BIOCHEMICAL EDUCATION IN PERSPECTIVE

by

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An Inaugural Lecture delivered on Thursday, 31st January, 1974, at the University of Ghana, Legon
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In these days of national awareness of the role science and technology can play in the industrial development of a nation, a topic on science education is likely to arouse considerable interest. Implicit in this statement is the conviction that principles learnt in science should lend themselves sooner or later to application to solutions of practical problems that plague mankind; and indeed, the various scientific and technological advancement in developed countries of the world clearly support this conviction.

In order for Ghana as a developing country to stand up to make similar achievement, we need to develop in our schools and Universities, science programmes, aimed at producing graduates who can apply their knowledge to solve practical problems of life. The Government of Ghana recognises this important role of science and technology and the Ministry of Education and the various Science Associations in the country have set themselves to formulate national science policies for the promotion of science education. It should be noted with interest that in recent months several meetings of science associations have been held in Accra to discuss science education programmes in schools. The latest of such meeting was that of the West African Union of Science Teachers Association. These trends point to the urgent need for providing pupils with a sound foundation in science at school level.

The Universities of Ghana are no less sensitive to this national problem of producing scientists of the right calibre and training for the nation. In this University, the new curriculum for First Degree Programme in science which has come into effect this academic year is generally aimed at improving the science education at the University level. The recent visit of a team of Ford Foundation Consultants to the University to help document the needs of the Faculty of Science for equipment required for teaching and research is another example of commendable effort the University is making to improve facilities for the training of future scientists.

The challenge is now thrown to science departments and institutions of this country to produce the type of scientific manpower urgently needed for our industrial development.
It is my task today as Head of Biochemistry Department to attempt to show how biochemists are being trained to tackle problems in the field. To discuss this issue I have chosen the topic "Biochemical Education in Perspective." In the discussions that follow, I shall give a general background information on the discipline of biochemistry, its growth and its relation to other sciences, what goes into the education and training of biochemists and the impact of biochemistry on society.

**Scope and History**

For some of you here, today may be the first occasion to have serious contact with biochemistry. To those uninitiated I have to sell the subject. The others who have already had contact with the subject, will surely be reminded of the problems and fascinating events that have taken place in the discipline.

Biochemistry is a relatively new branch of science compared with such old and venerable disciplines as Physics, Chemistry, Botany and Zoology. Compared with Zoology which is said to be the oldest of the sciences with its history dating back to about 500 BC, the history of biochemistry as an organised, separate discipline spans only through a century, most of it indeed, within the past forty years.

Historically, biochemistry has grown in close association with professional training, primarily with medicine. In the United States of America, biochemistry has also been strongly represented in Schools of Agriculture as in Universities of Wisconsin, Minnesota and in Cornell University. The first Professor of Biological Chemistry in the United States of America was Otto Folin, who was appointed to the Chair at Harvard University in 1905. In England during this period Sir Frederick Hopkins had organised biochemistry courses which had gained considerable influence and recognition as a subject of importance in its own right at Cambridge University.(3)

An impressive thing about this young science is that most of the people who have made great contributions to its development are still alive and are working in the field. In all accounts, biochemistry is a new discipline. Nevertheless, this young science has made great impact in the biological field through vigorous and high quality research. Biochemistry has now penetrated nearly all
the traditional areas of biology from taxonomy to genetics. For example, it is now possible to classify varieties of certain yams on the basis of the quantity and quality of amino acids present. Much more can be said about biochemistry and genetics; their association had been described by Professor Edsall in these words: “Genetics and Biochemistry indeed have entered into an indissoluble union: one cannot teach either of these subjects in any comprehensible way without becoming deeply involved in the other.”

What then is biochemistry? According to definition, biochemistry is a science that deals with the study of:

(i) the nature of chemical constituents of living things and of chemical substances produced by them.

(ii) the functions of the chemical constituents and the chemical processes that transform these compounds.

(iii) the energetic changes associated with the transformation, and

(iv) the whole question of genetic inheritance and related problems at molecular level.

Biochemistry like other sciences, is an experimental subject. The biochemist therefore attempts to understand the make-up and the dynamics of life at chemical or molecular level through experimental evidence. Since life is recognised by means of the functions and characteristics of living things, (including growth, reproduction, movement, responsiveness, adaptation, organisation and metabolism) the biochemist seeks to understand each of these functions in terms of chemical substances and chemical reactions involved.

The first stage in biochemical studies was mainly concerned with identification of the molecules that make up the living organism. This exploration was carried out by organic chemists and was more concerned with the description of the chemical constituents than with the dynamic processes that occur in living cells. The results of this work made great contribution to biochemistry because they led to the understanding of the structure of most of the chemical compounds that are present in biological systems. The major compounds of living things thus include carbohydrates, fats and oils all of which serve as main sources of energy to the cell; next, amino acids and proteins which are required for repair and building up of new tissues: some proteins however are enzymes which are able to catalyze chemical reactions in the cell; next, we have
nucleic acids: there are two main kinds — one type is deoxyribonucleic acid (DNA) which is the primary genetic material responsible for transmission of genetic characters from parent to offspring. The other nucleic acid, termed ribonucleic acid (RNA) is mainly involved in the biosynthesis of proteins, but in some virus it serves as the primary genetic material.

Other important chemical constituents of living things, are alkaloids (in plants) and vitamins. While alkaloids have great medicinal potential, vitamins on the other hand play important role in growth and cellular metabolism.

Indeed man and all other living things are made of chemical molecules, the most predominant chemical elements being Carbon, Hydrogen, Oxygen, Nitrogen, Sulphur, Calcium and Phosphorus. After death these chemical molecules decompose into gas and other non-living mineral substances. So then of what substance is ghost made? Sir Cyril Hinshelwood has aptly remarked “Every branch of biology which has material basis is in part molecular biology; the only exception, which is not in any way molecular, is spiritualism.”

Before the science of biochemistry got under way, people held the view that there was some force associated with living object. The debate over the existence of this vital force raged among scientists for many years. At last the several landmark achievements credited with ending the vital force concept are examples that have helped to put biochemistry in perspective historically. These precise achievements are described below.

In 1785, Lavoisier and Laplace, two French scientists, using a calorimeter, showed that a guinea pig respiring by consuming oxygen produced heat energy and carbon dioxide, the same way as burning enough carbon such as charcoal in calorimeter produced heat energy and carbon dioxide. Thus the relationship between carbon dioxide and heat produced was the same whether these were products of animal metabolism or of a simple chemical reaction. From this it was possible to show that living organisms obey the first law of thermodynamics which is the law of conservation of energy.

Secondly, it was felt that only living organisms could produce substances that were found in them. Such substances produced by the living organisms were termed organic as different from inorganic substance produced by non-living processes. For example
it was argued that urea found in urine of animals could only be found in living animals. Yet in 1828, Wohler, a German scientist, heating the inorganic substance called ammonium cyanate produced for the first time in the laboratory an organic substance, urea, which in all respect was identical to urea isolated from living animals.

Thirdly, Pasteur, a renown French scientist held the concept that only intact living organisms could bring about fermentation. For example only whole yeast could ferment sugar into alcohol. He maintained that fermentation was a living process believed to contain vital principle. Yet in 1897, Buchner and his brothers successfully obtained yeast extract by grinding yeast cells with washed sand and filtering to collect the extract. This extract which was free from living yeast cells was able to ferment sugar into alcohol. This discovery that vital process of fermentation could be catalysed by non-living constituents of yeast really marked the beginning of modern biochemistry.

The most recent landmark achievement has to do with transmission of hereditary characters. Mendel in 1865 discovered the fundamental law governing transmission of these characters. It was maintained that the hereditary factors termed genes were carried on chromosomes. In 1944, Avery and a co-worker were able to isolate from bacteria a chemical substance, identified to be DNA which was able to transform hereditary properties in a different strain of the bacteria. This discovery of the chemical nature of the gene now serves to refute the theory of mysterious vital force which had been associated with transmission of hereditary characters in living things. (7) (8) (14).

Perhaps the next intriguing area which needs to be probed is the biochemical basis of memory.

Knowledge gained from the study of the chemical compounds in living things set the stage for the study of the dynamic aspects of biochemistry. This is the area of study called intermediary metabolism which deals with how the molecules of biological systems are degraded and synthesised. All breakdown processes of the cell are energy-yielding whereas synthetic processes are energy-requiring. The energy in the molecule has originally come from the sun as radiant energy and has become converted into chemical energy by the process of photosynthesis. The chemical energy released from compounds during the breakdown process in cells
is converted into packets of energy currency called adenosine triphosphate (ATP). Thus ATP thus links degradative and synthetic processes of cells. It is also used for various work: for example, contraction of muscles, synthesis, and transport of chemicals in cells against concentration gradients. The biochemical mechanisms for these energy conversions to do synthetic, mechanical and transport work are well understood. Some examples of specialised energy transformations whose mechanisms are less understood are found in the firefly which releases flashes of light, and in the electric eel which is capable of delivering several hundred volts of electrical potential.

By 1960 the major pathways for the breakdown and synthesis of most chemical compounds of biological systems have been established. In the last decade, the stage of development in biochemistry has dealt with studies on integration of structure with function of the cell, regulation of the manifold biochemical reactions in the cell to achieve the greatest economy in the use of cellular material and energy, and the control of biosynthesis in general and specifically of enzymes that catalyse cellular reactions. The area of active research in recent years however is the relationship between heredity and biochemical make-up. This is the area referred to as biochemical or molecular genetics.

Biochemistry is now advancing so rapidly that many textbooks have been written on the subject. There are now so many journals of biochemistry and related fields reporting research findings that it is a difficult task to be able to catch up with all the journals. There is increasing flow of research reports extending new knowledge; some reevaluating or reinterpreting previous ideas. In 1972, a new dimension was added to biochemical literature by the publication of a quarterly bulletin on Biochemical Education. This bulletin of the International Union of Biochemistry provides a useful forum for discussion of matters relating to teaching and curriculum development in biochemistry, and training for industries and other fields. (4)

**Developing Curriculum in Biochemistry**

The importance of the chemical constituents of the cell has been stressed and that the study of these compounds requires a knowledge of organic chemistry has been indicated. Furthermore mechanism of enzyme action has its basis in reaction mechanisms in organic chemistry. Biochemistry cannot therefore be studied
without adequate background in organic chemistry which is itself undergoing constant extension, revision and refinement. These advances undoubtedly also influence concepts in biochemistry.

The second and third parts of the definition of biochemistry have to do with the dynamics of living organism which relates to the physiology, that is, the functions of biological systems. In this regard a knowledge of the different biological forms of life is essential to a student of biochemistry. Claude Bernard, Pasteur and their contemporaries have shown that on biochemical level, there is unity among the manifold forms of life (whether in human being or in animal; in plant or in micro-organism). This concept has been very important in comparative studies in biochemistry. Although there is some diversity in chemical activities of different biological forms, it is true that many fundamental biochemical reactions underlying cellular functions show a striking uniformity from the lowest to the most highly organised forms of life. It is, for example, now clear that chemical process studied in a yeast culture may elucidate comparable series of reactions in mammalian muscle.

Again, to correlate such physical phenomena as motion, electric conductance, absorption or emission of light and heat production in the living organism with its chemical process, a good knowledge of physics is necessary. The biochemist therefore must consider a physiological process not only in terms of the chemical nature of the substances involved in it but also in terms of the physical relations among the substances and of these substances to the environment. For adequate understanding of these phenomena he must rely on a body of knowledge in physical chemistry. To enable him to understand the energy relations in biological systems, familiarisation with thermodynamics is essential; and for full appreciation of the chemical dynamics of living things a knowledge of the kinetics of chemical reactions is indispensable.

From the above discussions it is obvious that a sound education in biochemistry requires a solid foundation in Chemistry, Biology, Physics and Mathematics. At this stage it is clear that the discipline of biochemistry resists classification as a biological or physical science. Indeed, most of the research in the field lies at the interface of physical and biological sciences. Thus biochemistry serves as a link between the physical sciences on the one hand and animal and plant sciences on the other.
In view of the rapid expansion in knowledge in biological sciences, increasing specialisation in biochemistry has become inevitable. It must however be said that happily such divisions have not abolished the intimate interrelationships that exist among the components of the major disciplines. Some important specialisations and related disciplines of biochemistry are: enzymology, molecular biology, clinical biochemistry, industrial biochemistry, nutritional biochemistry, biochemical genetics; biophysics, pharmacology, physiology, microbiology, endocrinology, immunology and genetics. Thus it can be seen that many separate streams of knowledge nourish the growth of biochemistry. The rapid development of the subject in recent decade is the result of important research findings in the field of biochemical genetics.

Departments of Biochemistry have often started from either Departments of Chemistry or Biological Sciences Departments. Thus the approach of education and training in biochemistry can vary from either the biological side or the physical side depending upon the objective of any one department. The emphasis too can vary: it can be on industrial, clinical, nutritional or engineering biochemistry. Nonetheless the main preoccupation of all Departments of Biochemistry is to ensure that a core of basic courses in biochemistry is provided. It is the variety of subjects that goes into the core course which presents a problem in the education of biochemist. As you can see from above, many different and related subjects should be studied. It is therefore not easy at times for biochemistry degree programmes to fit neatly into traditional degree structures such as 3:2:1, that is, three subjects in the first year, two in the second year and one in the third year. Occasionally, parts of other disciplines may have to be added to biochemistry to make it complete. For example, while taking advanced courses in biochemistry as a single subject, it may become necessary to study, say, a course in X-ray crystallography in order to gain full insight into the structures of macromolecules that are involved in dynamic processes of life.

In the face of accumulating mountains of courses required in biochemistry, it becomes tempting for a student to specialise as soon as the opportunity arises because if he spreads himself over the curricular landscape, he may end up in universal superficiality in the subject. Thus we have biochemists who are specialised in Proteins, Enzymes, Carbohydrate, Lipids or in Nucleic Acids, as
each is related to life. The danger of this system lies in specialising very narrowly at the expense of much that should be known. Another way of dealing with the problem of a wide variety of courses to be studied, is through the instrument of elective system. In this system, the student is able to select courses that appeal to him within the limits of the discipline. This is often done in consultation with the Academic Supervisor or the Head of Department. In this system there is need for proper integration of the courses learnt so that knowledge acquired does not lie about in fragments and never get welded together. The elective system has been common in American education whereas the system of high specialisation characterises the British education.

It is appropriate at this juncture to summarise the programme for training biochemists in the United States of America and in Britain where most of our scholars are trained. Until recently there was no undergraduate degree in biochemistry in the United States of America. Rather specialisation in biochemistry took place at the graduate level after a four-year undergraduate course leading to B.Sc. degree in chemistry as major subject with biology, physics and mathematics as supporting subjects. Even at the graduate level, a student working for the M.Sc. degree, requiring one to two years, takes a major course in biochemistry and a minor in another subject; such as chemistry, micro-biology, genetics, pathology, pharmacology, or physiology. For the Ph.D. degree, requiring a minimum of three years, a student takes biochemistry as a major subject and two minor subjects from related disciplines. Some Universities require two languages for the Ph.D. and one for the M.Sc. degrees. The graduate studies in biochemistry in the United States of America therefore involve both theoretical and practical training including thesis. At present there is a growing number of institutions offering B.Sc. degree in biochemistry in the United States of America. Usually about a third of the total B.Sc. programme may be devoted to molecular biology which is essentially biochemistry and the remaining two-thirds spread over electives in chemistry, physics, genetics, biology, modern language, statistics, and social science.

The British Universities on the other hand have for some time had full curriculum for B.Sc. degree in biochemistry. The undergraduate course usually takes three years. However very few Universities, apart from the Scotish Universities, run four-year undergraduate
courses. In this system, a student can take a single subject Honours degree within the 3 : 2 : 1 structure. There is also the possibility of two-subject Honours degree curriculum in which a student takes two subjects in the final year. No formal courses are usually taken at the graduate level under this system. (4) The degree of specialisation at undergraduate level is somewhat reduced in the new British Universities like East Anglia, Leicester and Sussex where biochemistry can be taken as a major in the School of Biological Sciences. Such studies lead to the B.Sc. degree in Biology. Clearly these new Universities in Britain have adopted the principle of major and minor subjects as practised in the United States of America.

Here in Ghana, a little over ten years ago when I started my University teaching career, there was hardly any organised biochemistry teaching. The University of Ghana had then conceived the idea of starting a Department of Biochemistry, Nutrition and Food Science. When the Department was established in 1963, the biochemistry initially taught was meant to support courses in Nutrition, Food Science and Home Science.

Meanwhile discussions were going on at the University of Science and Technology, Kumasi for the establishment of a Department of Biochemistry. After the University has had consultations with managers of relevant industries and officers of the then State Enterprises Secretariat, the Department of Applied Biochemistry was established in Kumasi in 1964 with a bias for fermentation biochemistry. To me the emphasis in both departments at Legon and Kumasi was not too different to warrant the establishment of the two separate departments in the country at that time of financial stringency. Yet neither of the two Universities was prepared to give up its department. On the basis of functions assigned to Universities in Ghana at that time the University of Science and Technology however seemed to have a slight edge over Legon in developing a Department of Applied Biochemistry at Kumasi. But soon the establishment of a Medical School in Accra tilted the balance much more in favour of establishing a strong department of biochemistry in Accra. In fact the Medical School had then established its own Department of Biochemistry in 1965. The Education Review Committee on delimitation of functions of University Institutions set up in 1966 by the then Government of Ghana recommended that the Department of Biochemistry at
Kumasi should be discontinued. The reason was that "it was unnecessary duplication since the department at Legon had been in existence for some time to cater for the proposed Home Economics and the Medical School; Kumasi could however teach the subject of biochemistry as part of other degree course." This recommendation was accepted by the Government for implementation. The actual implementation, however, turned out to be a tussel and could not be achieved and the two departments are still functioning. Incidentally, Professor A. A. Kwapong, Vice-Chancellor of the University of Ghana happened to be the Chairman of the Education Review Committee. The point should be made here that university autonomy coupled with academic freedom and perhaps university politics in this case submerged all other rational considerations to develop one strong Department of Biochemistry in the country. The two departments as they exist suffer considerably from inadequate equipment and staff, although each department has been striving hard and indeed is doing its best in the training of manpower needed in the field. There is certainly the need to bring such undesirable developments in our universities under control and it is hoped that the National Council for Higher Education will be in a position to carry out this responsibility.

Biochemistry at Legon

Teaching

The Department of Biochemistry at Legon as presently reorganised serves the Faculties of Science and Agriculture, and the Medical School. The admission requirements and the new degree structure for the undergraduate course in biochemistry have been published and are available in the University Bookshop. The salient features of the new curriculum as applied throughout the University are that the study programme covers a period of three years for the B.Sc. Degree and that subjects are divided into courses to allow for selection if necessary. Course units have been assigned to these courses. The most preferred combinations for the first year study is Chemistry, Biology and Physics with Mathematics. Other course combinations including Chemistry may also be acceptable for admission into the second year when a student studies biochemistry with another approved science subject. In the third year biochemistry is studied as a single subject or with a second science subject. Optional courses can still be taken if student's load permits. The
department also teaches such job-oriented courses as clinical bio-
chemistry and industrial biochemistry. Students undertake training
in industries and research laboratories during the long vacation
immediately following their second year's work. (11)

Research projects are also undertaken by the final year students
under the supervision of senior members. The project work is an
important feature of the degree structure since it trains students
to work independently and to gain confidence in themselves in
experimental work. To the staff who are often loaded with teaching,
the students' project gives opportunity to get themselves involved
in research in the process of training the students.

The biochemistry programme for preparing medical students for
the second M.B. examination is also based on a new curriculum
covering a period of three terms instead of five as before. This
new programme is in its second year of operation and so far the
results of the first group of students who took the second M.B.
examination last year have been encouraging: the level of achieve-
ment was quite high and compared favourably with that of the
5-term programme.

In the further training of medical students in biochemistry, the
department also has a one-year intercalated course leading to B.Sc.
degree in biochemistry. Medical students who perform very well
in the subject at the 2nd M.B. examination are normally recom-
manded for this course. After the one year course such students
go back to continue with their medical training. The first student
for this intercalated B.Sc. degree in biochemistry started with our
Honours students in October, 1973.

Lastly service lectures in biochemistry are given to Agriculture
and Home Science students.

Research

To avoid dissipation of research effort and funds over a number
of unrelated research work, the department has laid down two
research themes namely,

1. Biochemical investigation into malaria, antimalarial drugs
   and related problems.

2. Biochemical studies of cocoa diseases (these studies are
carried out in collaboration with Cocoa Research Institute, Taf). Staff and graduate research topics are normally selected from the
above themes. There are however a few research topics outside these themes which are already going on and have therefore been allowed to continue. A survey of research being carried out by staff in the department is as follows:

For some time past, I have been interested in the enzyme, Glucose-6 Phosphate Dehydrogenase (G6PD). This enzyme has been involved in sickle cell anemia where it has been shown to be deficient in patients. This factor, together with others, is responsible for the easy hemolysis that occurs in the red blood cells of sickle cell anemia subject. At the same time, the deficiency of this enzyme is claimed to confer some advantage against malaria infection in sickle cell anemia patients. Since the blood in which the malaria parasites inhabit does not stay long enough for the parasites to develop before the blood is hemolysed, the parasites do not mature to bring about serious infection.

My present interest in the enzyme, however, centres on the effect of adrenalin on its activity. The G6PD is the first enzyme of the shunt pathway for the breakdown of glucose to produce reducing equivalents required, among other things, for maintaining the integrity of cell membrane. The major pathway of glucose breakdown, however, leads to the production of energy for work in the body. When a person is frightened or is under stress, the hormone called adrenalin is released into the blood from the adrenal medulla of the kidney. This hormone increases the rate of glucose breakdown to give more energy required to combat the crisis. Adrenalin is therefore popularly known as the hormone of ‘fright, fight and flight’. This research has been designed to find out to what extent the hormone will control the G6PD (that is glucose going through the shunt pathway). Preliminary results show that about 20 per cent of the G6PD activity is inhibited by adrenalin. Implications of these results are being studied.

Another research in which I am interested is on the metabolism of Phytophthora palmivora, the causal agent of the black pod disease of cocoa. This fungus has been difficult to control in the field. The average loss of cocoa due to this fungal disease has once been reported to be 19 per cent over a five year period in Ghana. This would represent annual loss of about C44 million on present day cropping level. (6) This research project has been planned to study how this fungus utilises its substrates for the production of energy for its survival and how this process can be prevented. It
is hoped to gather from this research data that will be useful for
the development of suitable chemicals for the control of the disease.
Results so far obtained suggest that certain chemicals in low con-
centration would activate oxygen uptake in the fungus; however
higher concentrations would cause decline in the uptake.

Yet another research just started is on the possible interactions
between steroid hormones or contraceptives (as found in oral
contraceptives) and chloroquine in target tissue such as uterus.
It is known that certain steroid hormones can induce formation
of peroxidase enzyme in the uterus. This enzyme has been shown
to inactivate estrogens. An attempt is therefore being made to study
the activity of this enzyme in relation to chloroquine administra-
tion. It is hoped that information from this research will be useful
in Family Planning Programmes, especially those having to do with
the successful use of oral contraceptives in countries like Ghana
where chloroquine is widely used as prophylaxis and for treatment
against malaria.

Dr. B. Y. A. Andoh has been studying the chemistry and
metabolism of dapsone which is an antileprotic drug. Some of its
derivatives have been found to be effective antimalarial drug in sickle
cell anaemia patients who cannot be treated with such anti-malarial
drug as primaquine because of its hemolytic effect on red blood
cell. Dr. Andoh is also interested in analysing local foodstuffs
for their protein, carbohydrate, fats and oils and mineral contents.

Dr. P. Larway has been concerned with biochemistry of yam
respiration. Incidence of decay and high losses in weight of yam
has been reported during storage and transport; while the decay
is attributed to microbial activity, the loss of weight in yam is due
to high respiration (that is the breaking down of the carbohydrate
in presence of oxygen). Both factors can account for 10–25 per cent
losses in yam in storage for three to six months. Dr. Larway is
therefore interested in studying the rate of respiration in yam
at different temperatures. This research is aimed at finding
information for increasing the storage time of yam after harvest-
ing and during transportation.

Mr. K. K. Oduro has been looking into cocoa viruses in collabora-
tion with Cocoa Research Institute, Tafo. These viruses cause
considerable losses in the yield of cocoa. He has purified the swollen
shoot virus which appears to be rod-shaped but the yield is very low and more work is expected to be done. Another virus called cocoa necrosis virus has been isolated and purified by the Cocoa Research Institute group including Mr. Oduro.

Another work by Mr. Oduro is on Prekese fruit (Tetraplueura tetraptera). This fruit is used in preparing soup for women after delivery apparently for their well-being after the strain of child birth. Qualitative analysis so far done on this fruit suggests that it contains all the essential amino acids. These amino acids are important building units required for making protein. Since man cannot make these essential amino acids, they have to be supplied in the diet. Thus the nutritional importance of Prekese can be explained in scientific terms. Work is still going on to investigate the full potential of Prekese as a source of nutrients. When this finding is confirmed, Prekese extract could be used in fortifying food for weaning children against Kwashiorkor—a protein deficiency disease in this country.

Dr. B. Vadlamudi has been studying the red blood cell membranes with respect to their structure and function. This involves solubilization of the membranes followed by fractionation of various components, and determination of the function of the individual components. Preliminary results indicate that there may be differences in the proteins and lipids of the red blood cells from normal individuals and sickle cell anaemia patients.

Dr. F. N. Gyang is now engaged in the purification and characterisation of the enzyme, Aminopeptidase A in pig kidney. The objective of this work is to investigate the effect of the antimalarial drug, chloroquine, on kidneys using this enzyme as a means of measuring this effect.

Impact of Biochemistry on Society

I have already made the point about the useful research findings that are coming from biochemical genetics. Examples of some genetic diseases have been chosen to illustrate the importance of biochemistry in diagnosis and treatment.

First, the sickle cell anaemia which is found in people of tropical Africa and among American Negroes: this disease is heritable; that is, parents pass it on to their children. The biochemical basis of this disease has been established. The sickle cell hemoglobin (HbS) differs from that of the normal cell (HbA) by a single amino
acid substitution in the hemoglobin molecule. Under the control of DNA (the primary genetic material in the cell), the acidic amino acid, glutamic acid, at the sixth position of the beta-chain of the normal hemoglobin is replaced by the neutral amino acid, valine, in the mutant hemoglobin. This mutant hemoglobin in the variant cell now has 2–4 more net positive charges per molecule. This chemical substitution with its consequential changes in the physical properties of the hemoglobin gives rise to the sickling shape of the cell, followed by a host of physiological and clinical complications that are associated with sickle cell anemia. This disease occurs in an individual who has inherited this biochemical disorder from both parents. Where an individual inherits this disorder from only one parent, that gives rise to sickle cell trait which makes such individual a carrier of the disease. Such people may have normal life span. (13)

Another problem of health whose biochemistry is fairly well understood is called phenylketonuria (PKU) which comes under the classification of Biochemical Psychosis. Phenylketonuria is a hereditary disease caused by lack of the enzyme phenylalanine hydroxylase which converts phenylalanine to tyrosine. Synthesis of the enzyme is under genetic control. The disease, which occurs in one in about 20,000 births, is characterised by very high blood levels of phenylalanine and phenylpyruvic acid. Untreated phenylketonuria leads to mental retardation, behavioural disorders with psychotic features and fits. Most of the retarded women are also unlikely to have children. Those women with phenylketonuria who may show normal intelligence are in danger of producing retarded children. The reason for these defects seems to be that the high blood levels of phenylalanine cause damage to the brain and in women can damage the young developing baby while in the uterus. The higher the phenylalanine levels the more severe the damage or the retardation is likely to be.

The story is told in which a patient who has been unsuccessfully treated with electro-convulsive therapy (ECT) and drugs for psychotic episodes, was finally referred for biochemical investigation at a much later time. She was found to excrete large amounts of phenylalanine and therefore had phenylketonuria. A further investigation showed that the parents are heterozygote for phenylketonuria (that is, the parents are both carriers of the disease). Here is an example where biochemistry can be an important tool in diagnosis. Ideally, screening of pregnant women and children in the first week
of life for phenylketonuria is necessary in order to start early treatment. It has been known that the phenylalanine level in the blood can be reduced by a suitable diet containing no phenylalanine. This genetic disease can therefore be controlled by the use of selective diet. Another moral to this story is that all patients admitted to mental hospitals ought to undergo biochemical investigation in case there is a recognisable basis for their mental disturbance, otherwise, patients may in some cases receive inappropriate treatment. (10)

In the field of agriculture similar important contributions have been made. The development of high lysine in maize which has made tremendous impact in the nutrition of many million people in developing countries whose stable diet is corn and corn products, is the result of work in which plant breeders, biochemists and agronomists have played important role. By this work the nutritional quality of corn has been improved in respect of its essential amino acid content. (9).

Biochemistry has played important role in plant pathology. For example the crystallisation of Tobacco Mosaic Virus (TMV) by Stanley led to better understanding of the chemical nature of virus and its mode of infection. Tobacco Mosaic Virus has thus been used as a model for comparative studies of many other viruses. Biochemical studies of fungi and bacteria causing diseases in plants have been frequently undertaken to gain insight into the metabolism of these pathogens and how they can be controlled. (1) (2)

Graduates of biochemistry also make impact in industry. The latest analysis of employment pattern of biochemistry graduates in Britain shows the following distribution: 12 per cent to Industry, 30-40 per cent to Universities for further education. The rest go into various employment, teaching in schools has been the most popular where the graduates teach Chemistry and Cell Biology. Of the 30-40 per cent who obtain Ph.D. degrees, 12-15 per cent finally go to industry and about 50 per cent stay in research. The distribution of biochemistry graduates with first and second degrees in industries is as follows:

<table>
<thead>
<tr>
<th>Industry</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pharmaceutical</td>
<td>50%</td>
</tr>
<tr>
<td>Foods</td>
<td>15%</td>
</tr>
<tr>
<td>Drinks</td>
<td>10%</td>
</tr>
<tr>
<td>Agricultural Products</td>
<td>10%</td>
</tr>
<tr>
<td>Soap, Tobacco, Rubber &amp; Chemicals</td>
<td>15%</td>
</tr>
</tbody>
</table>
In Japan, the percentage of biochemists among other scientists in a typical industry has risen from 4 per cent in 1942 to 23 per cent in 1972. If associated scientists in the field of fermentation were included the respective figures rose from 14 per cent to 62 per cent. This shows a significant move in Japan to use more biochemists in their industries. (4) (5) (12).

In Ghana, within the past decades, about 96 Honours graduates (excluding General Degree graduates) have been produced from the Biochemistry Departments at Legon and Kumasi. Of these about 30 per cent have continued for M.Sc. and Ph.D. degrees. This figure compares very well with the statistics for graduates in Britain where 30–40 per cent of the graduates remain in Universities for further education. It is significant to note that about 6 per cent of our graduates with higher degrees have now taken up appointment in Universities at Legon and Kumasi. About 12 per cent has been employed in the Breweries and Distilleries in Ghana. I note with a sense of great pride that the Chief Chemist and the assistant Chief Chemist of a giant modern brewery in this country are both products of the biochemistry programmes which started in the country about ten years ago. Food and Pharmaceutical industries take about 10 per cent of the graduates. The rest have found employment in the Research Institutes, Hospitals, Government Chemical Laboratory, National Standards Board, Water and Sewerage Corporation, Agriculture and in school teaching. (Unpublished personal survey).

Problems and Future Development

Although there are no manpower requirement data for biochemists at the moment, one can see a great deal of opportunity for graduate biochemists in this country. Biochemists with Ph.D. qualifications are now wanted to fill positions in our Universities and the Research Institutes of the Council for Scientific and Industrial Research (C.S.I.R.). There is at present great potential for biochemical research in the country, but the limitation is rather one of a lack of adequate number of trained personnel than of equipment, although the latter is no less important in any successful research undertaking. I however maintained that with adequate maintenance of existing research equipment in the country, coupled with proper co-ordination and planning in the use of these instruments, much research work can be done provided there are enough research scientists.
The status of research in the country can therefore be raised to a respectable level if we can have a good number of our own people in research to ensure a stable cadre of research scientists.

In addition to training biochemists for existing industries, there are still other factors that will cause increase in the demand for biochemists. These factors include:

(i) Establishment of new research units; for example, the new Centre for Scientific Research into Plant Medicine at Mampong-Akuapim, and the National Environmental Protection Council will need biochemists on their staff.

(ii) Establishment of new industries; for example, the Bacchus Limited—a fermentation technology factory recently inaugurated in Kumasi, and the proposed soap manufacturing plant by the Ghana Industrial Holding Corporation.

(iii) Increasing demand for biochemical information on drugs and food additives used by human beings and in feed for livestock, as well as information on pesticides and chemicals in cosmetics.

(iv) General awareness of the potential of biochemistry in industries, not yet fully appreciated.

There must therefore be increased effort in the training of biochemists at both undergraduate and graduate levels now to be able to meet these future demands for graduate biochemists.

Admission of science students to biochemistry course in this University is now on the increase even though there has been a decline in the total intake into the Faculty of Science. This trend clearly indicates the popularity of biochemistry. The Department also admits about 60 medical students every year for the 2nd M.B. course. There are also service lectures to students of Agriculture and Home Science. The Department handles large classes of 60 or more students who ideally have to be given laboratory classes at a time. This creates formidable problems for the Department at the moment in getting large laboratories and equipment. A large laboratory for 60 students is therefore urgently required in addition to the recent extensions being made in the Department. It should also be noted that the equipment required for giving a good laboratory course in modern biochemistry are very elaborate and expensive. The University should therefore be sympathetic to our
requests for these amenities to enable the Department to carry out its normal functions. To supplement the effort of the University in this direction, industries and private organisations which are potential users of scientists should make substantial donations towards training programmes in the University. Secondly, the Council for Scientific and Industrial Research (C.S.I.R.), the only major research organisation in the country, should consider sponsoring graduate research programmes in the University in the same way as the Medical Research Council of Britain and similar Research Councils in the developed countries are doing.

Finally, it will be seen from today's lecture that biochemistry stands centrally among the physical, biological and, to some extent, the behavioural sciences. The discipline has also had close association with such professional training as medicine, pharmacy and agriculture. On account of its impact on industries, it also has conceptual affinities with economics, engineering, business administration and management. It is my hope that within the next quarter century, it will be possible to improve upon the present traditional curriculum for the training of biochemists to include some courses in these pertinent disciplines to promote greater interaction between the biochemist and the society in which he lives.
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